



The “Sitka Hurricane” in South-Eastern Alaska in the Year 1880

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Abstract

The extra-tropical cyclone called “Sitka hurricane” of October 1880 was one of the strongest storms ever to be recorded in the Gulf of Alaska. The *USS Jamestown*, a military ship moored off the Sitka harbour when the storm made landfall, observed an extremely low pressure of 958 hPa at sea-level and winds of 12 Beaufort. The aim of this study was to analyse this storm in version 2c of the Twentieth Century Reanalysis (20CRv2c), in which the *USS Jamestown* observations were not assimilated. Because the next assimilated pressure measurements are located more the 1000 km south of Sitka, the storm cannot be found in the 20CRv2c ensemble mean; but multiple ensemble members simulate wind speeds close to the observations. In particular, two ensemble members show a similar pressure and wind-speed evolution at the right time and location. However, they deviate in the observed passage of a cold front and in the location the cyclone deepening. Thus, none of the ensemble members reflects exactly the atmospheric state during the evolution and land-fall of the “Sitka hurricane”. Digitizing and assimilating additional early instrumental data, such as the log books from ships is crucial for future improvements of reanalysis products that reach into the 19th century.

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1. Introduction

The south-east of Alaska lies within the zone of mid-latitude westerly winds. Winter storms are common phenomena, but cyclones are usually in their spin-down phase (cyclolysis) in this region and hence not severe (Martin et al., 2001). If devastating storms occur, they are mostly remnants of tropical cyclones that undergo extra-tropical transition and become strong non-tropical systems. This was the case, for instance, in October 2015 when remnants of Pacific Typhoon Oho hit the region of Ketchikan with wind gusts of more than 120 km h^{-1} and 180 mm of precipitation in a single day.

The lowest sea-level pressure in the region (958 hPa) was recorded on 26 October 1880 by the *USS Jamestown* in the harbour of Sitka ($57^{\circ}3' \text{ N}$, $135^{\circ}20' \text{ W}$, UTC -8 h), before a permanent weather station had been installed. This cyclone created the so-called “Sitka hurricane”, which was one of the strongest storms ever to be recorded on the north-western coast of North America. The analysis of the event by means of historical data, ship logbooks, newspapers and written weather reports (Mock and Dodds, 2009) revealed that this storm did not originate from a tropical cyclone. Mock and Dodds (2009) tracked the origin of the cyclone back to the Sea of Okhotsk, Western Siberia (Fig. 1). The passage of the cyclone induced a sharp drop in pressure on the morning of 26 October 1880 in Sitka. At the same time, the wind reached its maximum speed of up to 12 Beaufort and the cold front decreased the temperature from 12 to 3 °C. The wind direction was from the east before the drop, changed to northeast with the drop and to southeast when the pressure was rising again. This suggests that the centre of the cyclone was south of the town of Sitka. Gale force winds and low temperatures well away from the lowest pressure, such as revealed by the diary of Edward William Nelson and Edward Alphonso Goldman at St. Michael, Alaska, and at St. Paul Island, Alaska illustrate the large extratropical nature of this storm.

The main limitation to better understand the evolution of this rare and extreme event is data availability. Now, with version 2c of the Twentieth Century Reanalysis (20CRv2c), a 6-hourly resolved global reanalysis that reaches back to 1851, there is the potential for an in-depth analysis of this storm (Compo et al., 2011). However, it is not clear if or how well the storm is resolved in 20CRv2c. A lack of observations in the northern Pacific may result in a

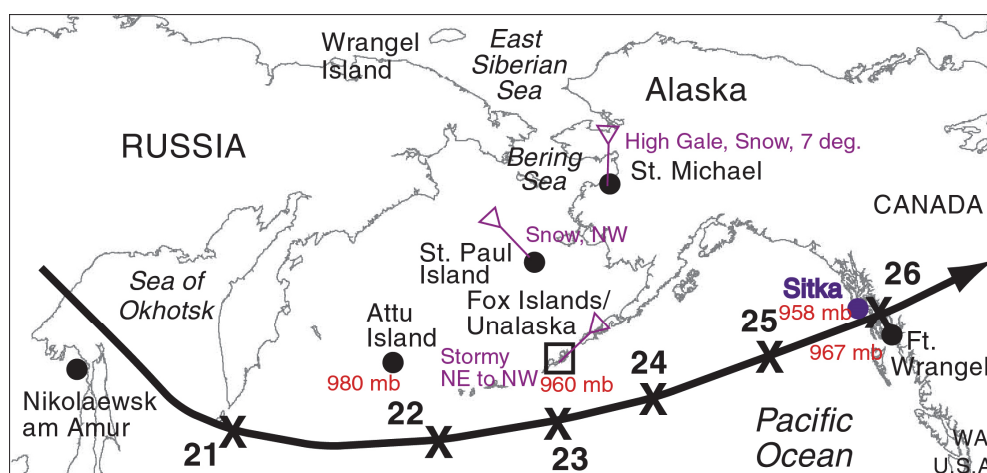


Figure 1. Reconstructed track of cyclone (modified from Mock and Dodds, 2009).

large ensemble spread. In this case, single ensemble members could still show a storm, which agrees with the large-scale circulation pattern. The aim of this study is to identify storm patterns in the North Pacific related to the 1880 “Sitka hurricane” in 20CRv2c.

2. Data

In this section, we describe the data and methods used in this study. The data comprise a reanalysis data set as well as independent instrumental observations.

Version 2c of the 20CR (Compo et al., 2011) is used in this study. Only 6-hourly observations of surface pressure from the International Surface Pressure Database (ISPD) version 3.2.9 (Cram et al., 2015) have been assimilated (Fig. 2). Additionally, monthly sea-surface temperature and sea-ice distributions have been prescribed as boundary conditions for the atmosphere model. The sea-surface temperatures consist of an 18 members ensemble from the Simple Ocean Data Assimilation with sparse input (SODAsi) version 2 (Giese et al., 2016) with the high latitudes corrected to COBE-SST2 (Hirahara et al., 2014). We will investigate both, the 20CRv2c ensemble mean and the ensemble members.

The distribution of assimilated pressure measurements on the day of the storm (Fig. 2) highlights a lack of observations in the northern Pacific in the year 1880. The closest stations lie over a thousand kilometres to the south in the Northwest of the United States of America. The data from the *USS Jamestown* was not included in 20CRv2c.

Observations mainly come from the *USS Jamestown*, which was moored off Sitka when the storm struck the coast. They consist of hourly observations of temperature, pressure, wind force, as well as 12-hourly water temperature measurements and qualitative description of the weather situation (Mock and Dodds, 2009). Additional observations, published in the same study, were recorded by the USCS schooner *Yukon*, south of Unalga Pass/Unalaska.

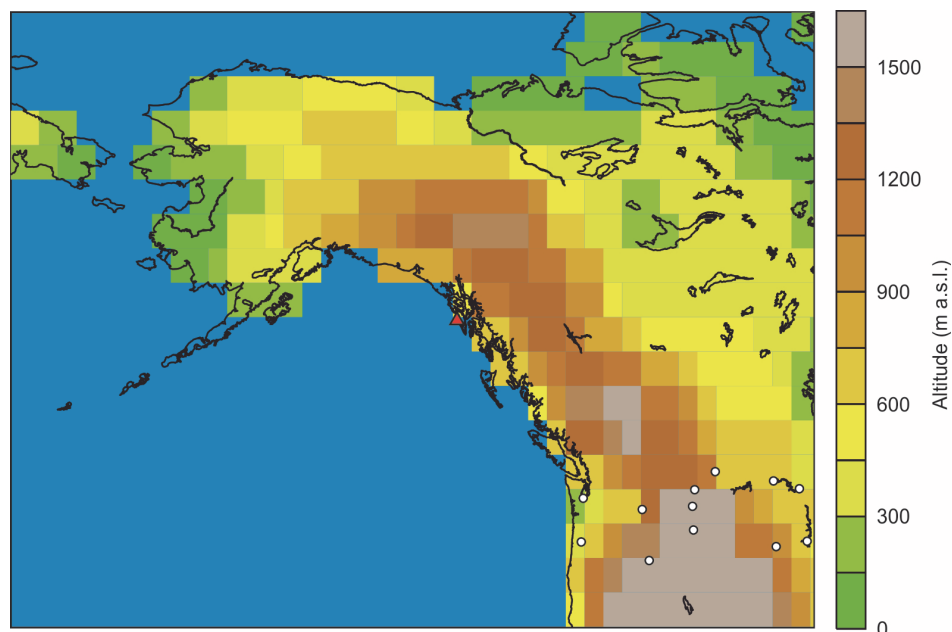


Figure 2. Locations of pressure observations (white points) on 26 October 1880, 12 UTC in the International Surface Pressure Database (IPSD) version 3.2.9 and the location of Sitka (red triangle).

3. Results

3.1 The “hurricane” in observations and the 20CRv2c ensemble mean

First, we examine the time series of the grid box that includes the town of Sitka in the 20CRv2c ensemble mean and compare these to the observations from the *USS Jamestown*. The evolution of mean sea-level pressure in 20CRv2c is nearly constant during the period from 3 days before until 3 days after the “hurricane” (Fig. 3). Pressure decreases slightly from 1008 hPa on 22 October to the minimum of 1000 hPa in the night between 24 and 25 October 1880. The date of the minimum appears already one and a half day earlier than in the historical data. In contrast to the 1000 hPa of the 20CRv2c ensemble mean, the observational data shows a very strong pressure drop from 998 to 957 hPa within 15 hours on 26 October 1880.

The temperature evolution of the ensemble means does not drop as would be expected due to the passage of a cold front (Fig. 3). The temperature measurements from the *USS Jamestown*, however, show a remarkable temperature drop of 9 K in only 4 hours.

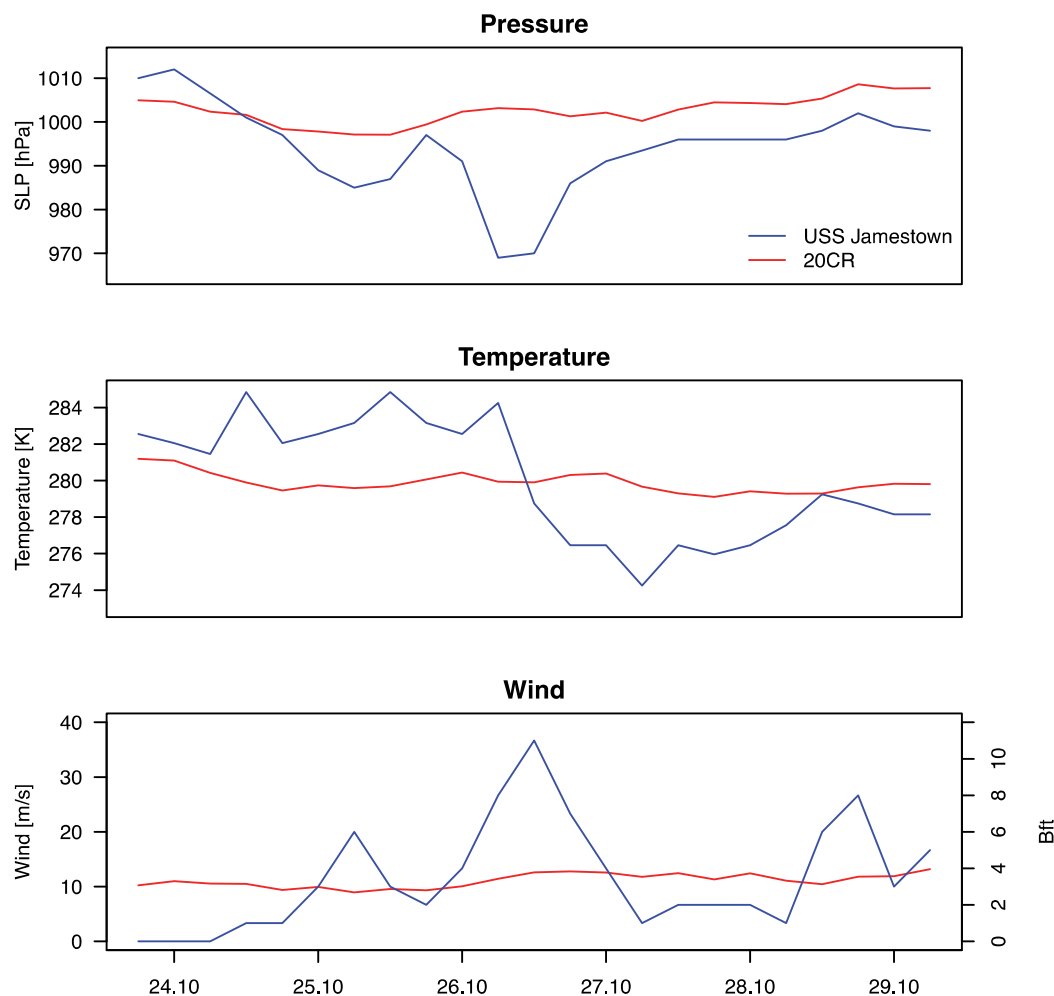


Figure 3. Time series of the 20CRv2c ensemble means (red) and the *USS Jamestown* measurements (blue) for mean sea-level pressure (top), air temperature (middle) and 10-m wind speed (in m s^{-1} for 20CRv2c and Bft for observations, bottom) in. Dates represent local time (UTC -8 h).

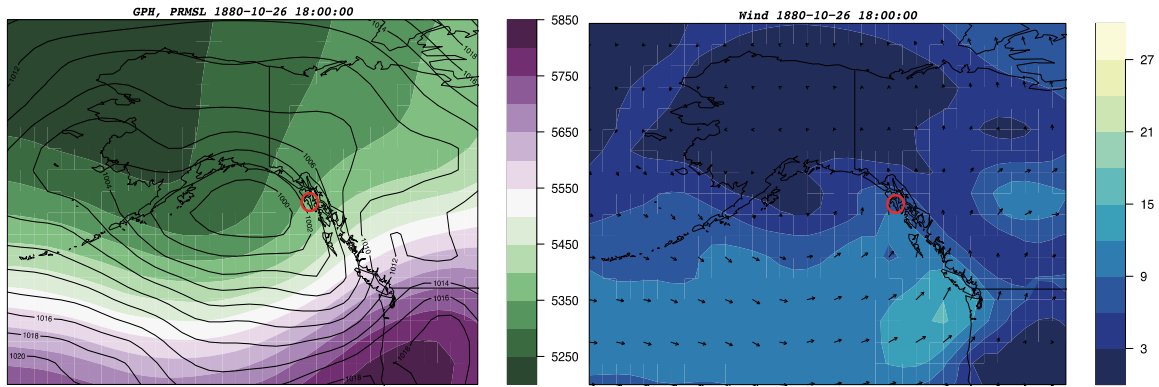


Figure 4. 20CRv2c ensemble mean geopotential height (shading, left) and sea-level pressure (contours) over the North-East Pacific on 26 October 1880, 10:00 AM local time, when the Sitka hurricane made landfall. Ensemble mean wind speed (shading, right) and direction (black arrows) for the same time and region.

Wind speed of the reanalysis data reaches 6 m s^{-1} (4 Bft) and does not denote a storm within grid boxes around Sitka, whereas the wind force observations show a major peak (10 and 12 Bft) on 26 October 1880.

Over the period from 22 October to 1 November 1880, none of the variables of temperature, sea-level pressure and wind speed shows noticeable features that point to a severe storm at the grid boxes around Sitka. A look at the entire northeast Pacific region in 20CRv2c reveals a weak low-pressure system (1002 hPa), which was located in the Gulf of Alaska southwest of Sitka, at the time when the *USS Jamestown* observed the “hurricane” (Fig. 4). Because the nearest assimilated pressure observation is located more the 1000 km south of Sitka (Fig. 2), the 20CRv2c ensemble means does not show a storm. Individual members might nevertheless exhibit realistic cyclones. To further investigate this possibility, we look at the single ensemble members as well as temporal and spatial shifts.

3.2 Single Ensemble Members

Because there are no storm patterns in the ensemble mean, we analyse the single ensemble members to identify model runs, which resolved a storm in the area of interest. Sitka is right at the edge of two grid boxes in the model, the mostly land covered box $57\text{--}59^\circ\text{N}$ and the mostly ocean covered grid box $55\text{--}57^\circ\text{N}$. As Sitka is right at the coast the latter is likely more representative for the conditions in Sitka during westerlies. Time series of all ensemble members at the grid cell south of Sitka have a large ensemble spread for all variables. Pressure on 26 October 1880 ranges from about 960 to 1030 hPa, temperature from -5 to 12°C and wind speed from almost 0 to 30 m s^{-1} (Fig. 5).

The ensemble members #25 and #38 (green and orange curve in Fig. 5a) are the members that have the most pronounced pressure drop within the period when the storm was observed. In member #38 pressure decreases from 1007 hPa on 24 October 1880 to 973 hPa on 26 October 1880. In member #25 pressure is already low with 990 hPa in the evening of 25 October 1880 but in the afternoon of 26 October 1880 it drops further down to 960 hPa. After the drop, the pressure increases again in both members.

Temperature drops in ensemble members #25 and #38 in the evening of 26 October 1880, only a few hours later then in the observations of the *USS Jamestown* (Fig. 5b). The temperature evolution of member #25 is much closer to the measurements with relatively constant temperatures of 8 to 10 °C before the event and a drop down to 3 to 5 °C during the following days. Only the amplitude of the temperature drop is around 2 °C smaller in 20CRv2c.

Wind speeds of 12 Beaufort have been visually observed on the *USS Jamestown*, which equals around 33 m s^{-1} . Four ensemble members (#6, #33, #48 and #49) reach wind speeds above 30 m s^{-1} between 25 and 27 October 1880. These values are grid box averages and will likely be lower than local wind maxima. Hence, some 20CRv2c members clearly reach observed wind speeds. A little bit to the south of Sitka (132° W , 52° N), wind speed in one 20CRv2c ensemble member even exceeds 34 m s^{-1} on a grid box level. Wind speed in ensemble member #25, which matched best to observations in terms of temporal sea-level pressure and temperature evolution, exceeds 28 m s^{-1} on a grid box average and thus are also in agreement with local observations of 12 Beaufort.

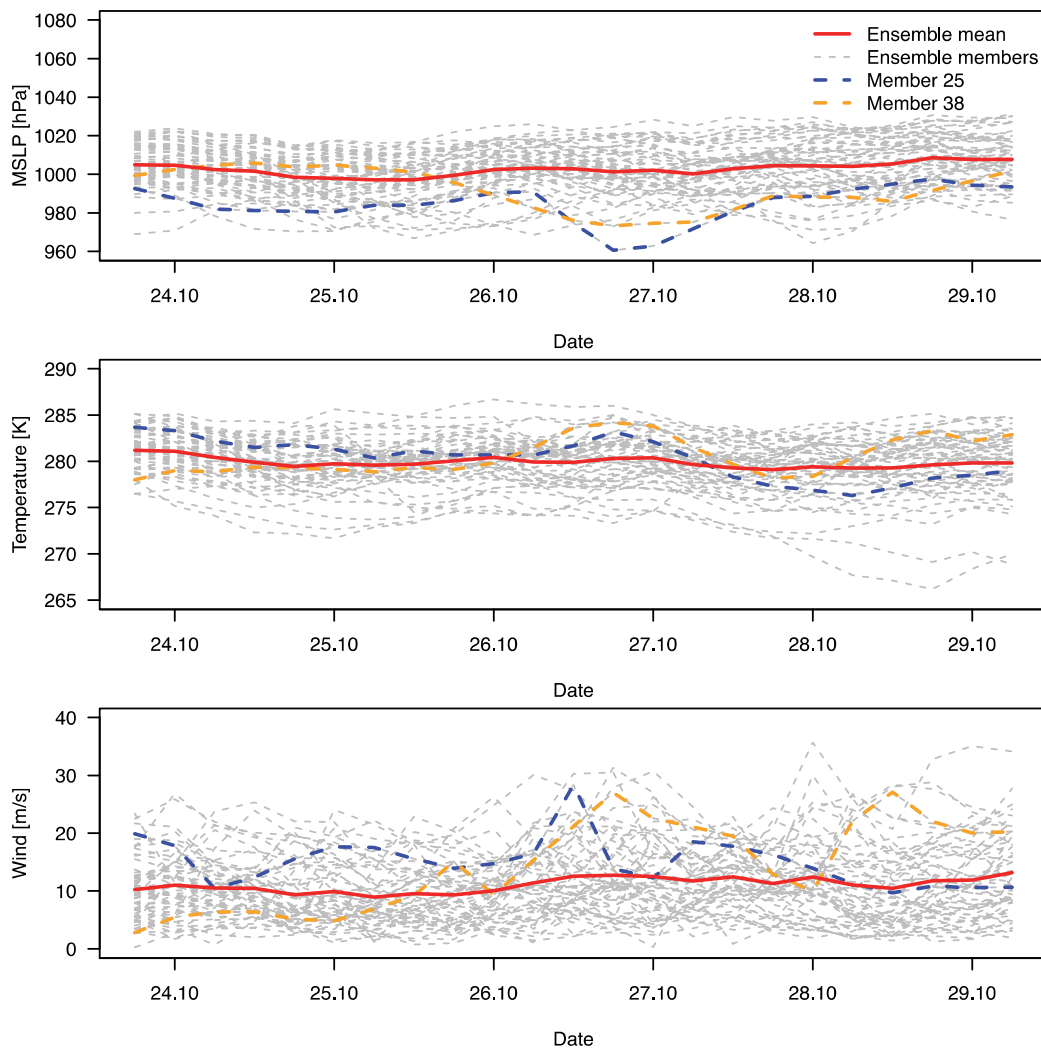


Figure 5. Time series of the 56 ensemble members (dashed grey lines), ensemble mean (red line) and two ensemble members (#25 dashed blue line, #38 dashed orange line) of mean sea-level pressure (top), air temperature (middle) and wind speed (bottom) for the nearest grid point to Sitka. Data in local time (GMT-8).

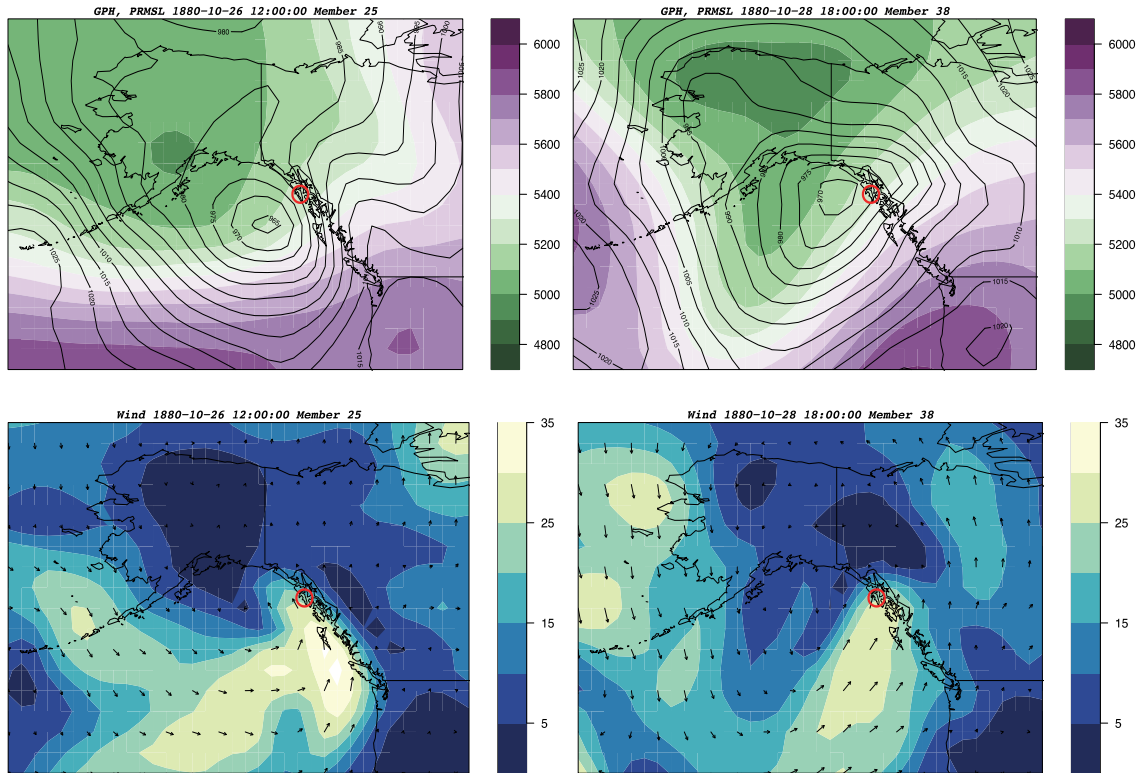


Figure 6. Wind speed (shading) and direction (arrows) over the North-East Pacific for the ensemble member #25 on 26 October 1880 04:00 local time in Sitka (left) and #38 (right) on 26 October 1880 10:00 local time.

In member #25 the centre of the low-pressure system with below 965 hPa is located to the southwest of Sitka already 8 hours before the observed hurricane. At this time, highest wind speeds of more than 35 m s^{-1} on a grid box level are reached close to the Canadian coast a few hundred kilometres south of Sitka (Fig. 6). In the grid box at the southern edge of Sitka wind speeds during this storm were still close to 30 m s^{-1} . In ensemble member #38 the timing is even more correct with the low-pressure centre of below 970 hPa just west of Sitka at the time of the event. Also in this ensemble member, grid box average wind speeds are close to 30 m s^{-1} on the southern edge of Sitka (Fig. 6).

In these two ensemble members the cyclone travels over the northern Pacific Ocean on a track similar to that proposed by Mock and Dodds (2009). Member #38 has a block over the Bering Strait region which deviates the cyclone track southward between 22 and 24 October 1880. A cut off exists on the 22 October 1880 in the Aleutian region, which moves eastward and deepens when it reaches a 500 hPa through close to the Alaskan/Canadian coast.

Member #25, in contrast, has no pronounced upper level waves and thus nearly zonal flow. A weak cyclone moves from the Aleutian region on 22 October 1880 eastward and intensifies as well shortly before making landfall at the west coast of North America.

4. Discussion

The ensemble mean of the 20CRv2c reanalysis does not show a severe storm when the so-called “Sitka hurricane” was observed in October 1880, neither in the surrounding days nor the adjacent area. Indeed, the ensemble means of the variables change only very slightly over

time because single extreme members get smoothed out. The ensemble spread is large due to the lack of observations in the northern Pacific region including Canada, Alaska and ship log books. The closest pressure observation, which got assimilated, is located more than a thousand kilometres from Sitka in Washington State, United States. Neither observations of the *USS Jamestown* nor the *USCS Yukon* were included in the 20CRv2c reanalysis.

In two of the ensemble members (#25 and #38) sea-level pressure and wind speed evolve similarly to the observations of the *USS Jamestown*. However, in contrast to observations, temperatures in both members start to decrease with a delay of a few hours and not as rapidly as observed. In both members the cyclones can be tracked back to the Aleutian region and they follow a commonly observed storm track eastward over the North Pacific (Rodionov et al., 2007). In contrast to a text book cyclone deepening around the Aleutian Arc, a region with strong baroclinicity, and a weakening at the Alaskan/Canadian coast, the cyclones in both 20CRv2c ensemble members are weak in the Aleutian region and deepen close to the coast. This disagrees with observations from the *USCS schooner Yukon* south of Unalga Pass/Unalaska on 22-23 October 1880 (Mock and Dodds, 2009), where already a strong cyclone was measured with 960 hPa pressure at its centre. Snow observation in north-western Alaska (Fig. 1) appear very unlikely with the Bering Strait block in ensemble member #38.

We conclude that 20CRv2c ensemble member #25 is closest to observations at Sitka and in terms of the reconstructed cyclone track by Mock and Dodds (2009), which itself is based on the interpretation of sparse observations. However, that late deepening of the cyclone close to landfall disagrees with observations south of Unalga Pass. Hence, none of the 20CRv2c ensemble members simulated the exact weather evolution of the Sitka hurricane. Nevertheless, multiple ensemble members indicate weather conditions that lead to a storm with observed wind speeds in the grid cells surrounding Sitka around 26 October 1880.

5. Conclusions

The aim of this study was to identify if the so-called “Sitka hurricane” in October 1880 was resolved in version 2c of the Twentieth Century Reanalysis. Despite its designation, this was not a hurricane that developed from a tropical cyclone transition but an extra-tropical storm. Due to a lack of assimilated observations in the North Pacific, the ensemble spread in this region is large and hence no storm is visible in the ensemble mean. Hurricane strength storms in single ensemble members highlight that large scale atmospheric conditions allow for a strong storm to develop. Two ensemble members appear similar to the observed storm but deviate in their temperature evolution and the location of cyclone deepening. Including newly digitized information from data sparse regions, such as log books from ships, will be crucial for future improvements of 20CRv2c and other reanalysis that extend back into the 19th century.

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